Materials for Ground Platform Survivability

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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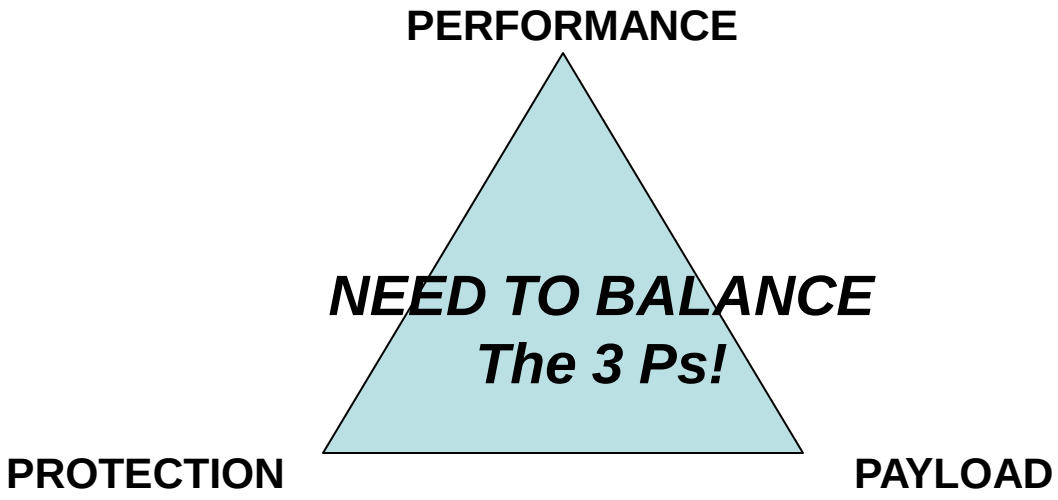
Outline

- Motivation
- Threats
- Types of Armor
- Armor Materials
- Armor Material Research
- Armor Standards
- Areas of Opportunity
- Conclusion / Questions

Motivation

DRIVERS

- **Lightweight / Mobile**
- **Threat Designable / Repairability**
- **Armor: Multifunctional Ballistic / Structural / Stealth**



Why Armor?

Attributes, Capability Gaps, Required Capabilities

Attributes	Capability Gaps	Required Capabilities
Protection	• Detect and neutralize mines and IEDs at standoff • Armored and light vehicle protection against kinetic, chemical, and tandem blast warheads • Occupant protection against IEDs and mines	• Provide occupant protection against IEDs, mines, CBRN, small arms, ATGM, RPGs, artillery, mortar, and direct fire • Prevent/Detect/Avoid engagements of platform from rapidly adapting threats and prevention from fratricide
Network	• Non-interrupted communications for dispersed units • Mounted and dismounted communications and situational awareness for dispersed units • Communications and surveillance at all echelons	• Provides Mission Command functions while moving • Open architecture to facilitate the integration of current and future communications, computers, and sensors • Interoperability with current and future communications systems, Army and JIIM systems • Control unmanned air and ground systems
Mobility	• Maneuver for positional advantage across range of terrain • Non-maneuver element mobility and survivability	• Manpower, maneuverability, firepower, and protection necessary to close with the enemy • Carry the required crew, squad, and payload for mission • Provide assured mobility (cross country, urban, and operational maneuver) across the full range of terrain • Negotiate urban obstacles and control points • Provide stability and appropriate center of gravity to prevent rollovers
Lethality	• Direct fire overmatch against high threat targets • Non-lethal weapons to achieve effects while limiting casualties and collateral damage • Organic precision indirect fires, especially in support of dispersed units	• Organic weapons for overmatch **like** enemy direct fire threats • Fight in all weather conditions, day and night, in complex terrain, including battlefield obscurants; identify hostile, friendly, or neutral people, allowing the crew to apply precise, lethal or non-lethal effects

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http://contracting.tacom.army.mil/majorsys/gcv/gcv.htm

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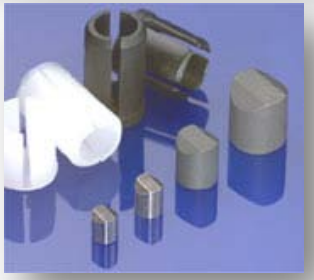
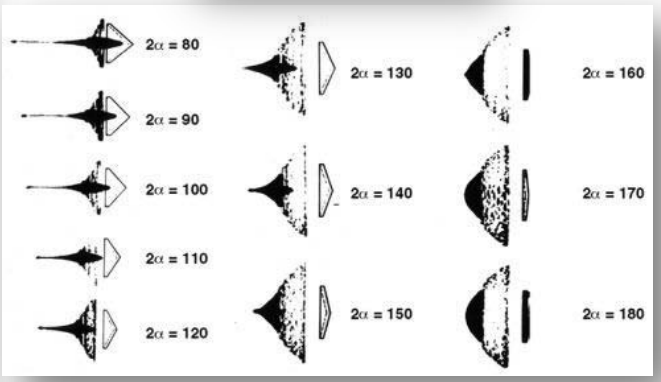
Threats

- 2 Main Categories
  - Kinetic Energy
    - Bullets
    - 5.56mm, 7.62mm, 12.5mm, 14.5 mm and larger
  - Chemical Energy
    - Shaped Charged Jet
      - Rocket Propelled Grenade (RPG)
    - Explosively Formed Penetrator (EFP)
    - Improvised Explosive Device (IED)
    - Mines



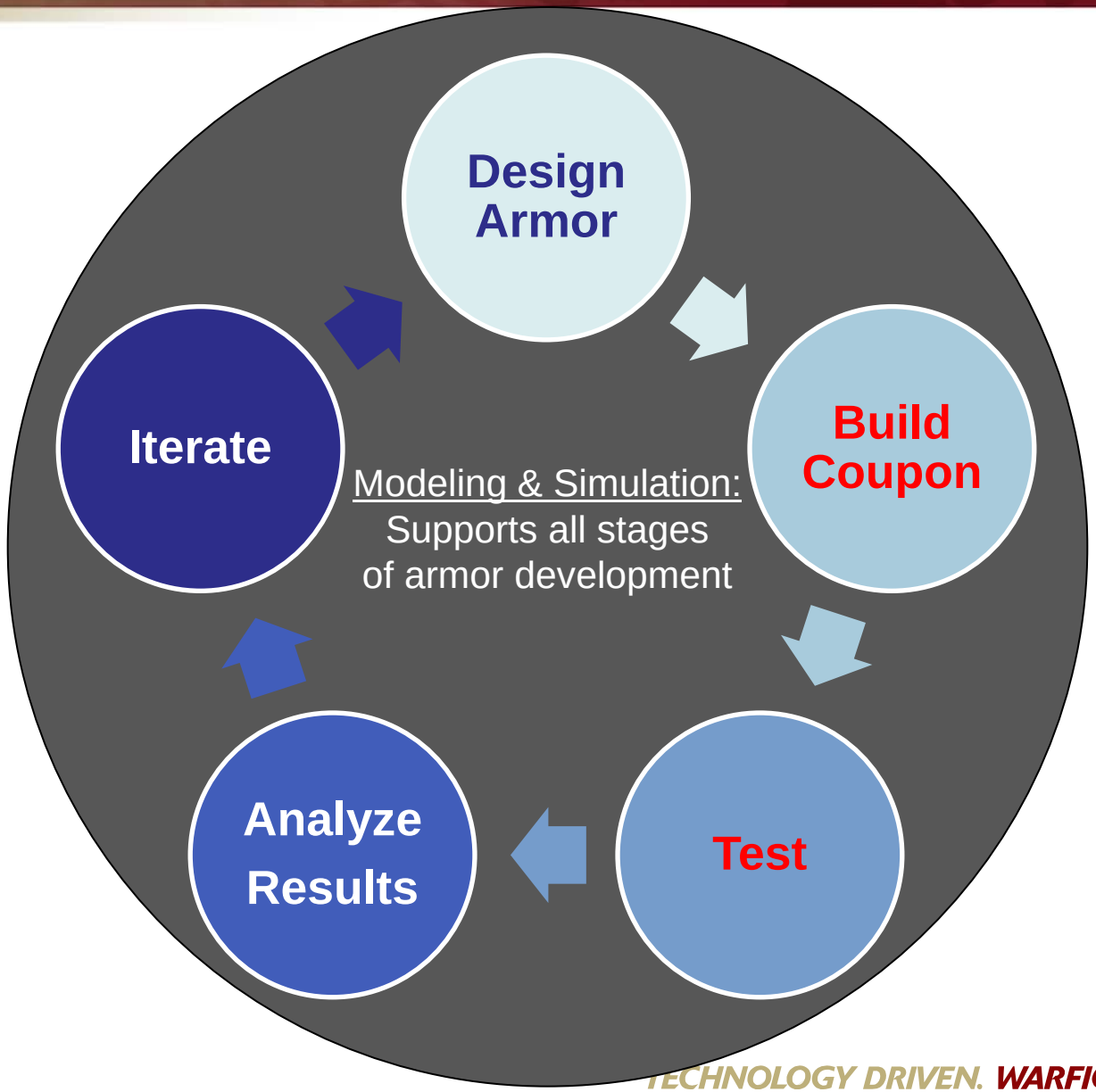


Armor Design

- **Optimal use of mechanics and materials**
  - Understand/use mechanics to obtain desired effect
  - Use materials that will amplify the performance of the mechanics
  - Demand “ultimate” performance from materials

Numerical simulations are an integral portion of any armor program, providing understanding and direction

Armor Development Process



Types of Armor

- All Armor Has One Purpose: **Protect the Soldier!!!**

- Soldier Body Armor
  - Vest
  - Helmet
  - SAPI Plate (Small Arms Protective Insert)
  - ESAPI Plate (Enhanced SAPI)

- Vehicle Armor
  - Opaque
    - Exterior Armor
    - Spall Liner
    - Hatches / Openings
  - Transparent
    - Armored Sensors
    - Windows

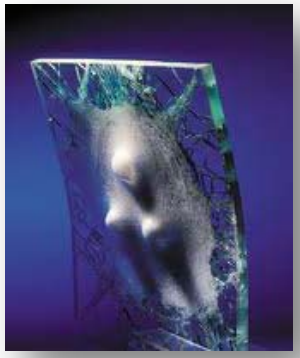
Traditional Armor Material's

- Metal's:
  - Steel
    - Armor Plate, Steel, Wrought, Homogeneous (for Use in Combat-Vehicles and for Ammunition Testing) (MIL-DTL-12560)
    - Armor Plate, Steel, Wrought, Ultra-High-Hardness (MIL-DTL-32332)
    - Armor Plate, Steel, Wrought, High-Strength, High-Quality (MIL-A-46186)
    - Perforated Homogeneous Steel Armor (MIL-PRF-32269)
  - Aluminum
    - Armor Plate, Aluminum Alloy, Unweldable Applique 6061 (MIL-DTL-32262)
    - Armor Plate, Aluminum Alloy, Weldable 5083, 5456, and 5059 (MIL-DTL-46027)
  - Titanium
    - Armor Plate, Titanium Alloy, Weldable (MIL-DTL-46077)

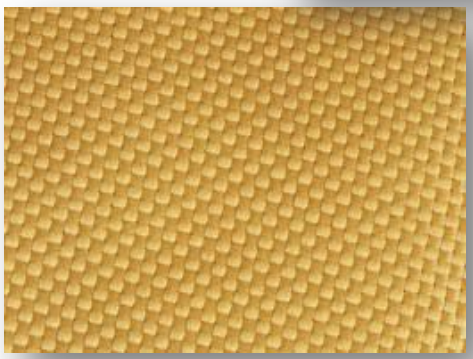
M88A2

Advanced Armor Materials

- Glass
  - Soda-lime
    - Ex. Starphire
  - Borosilicate
    - Ex. Borofloat
  - Glass Ceramic



- Fibers
  - Glass
    - Ex. S-2 Glass
  - Carbon
  - Para-Aramid Synthetics
    - Ex. Kevlar
  - Ultra-high-molecular-weight polyethylene
    - Ex. Dyneema / Spectra Shield



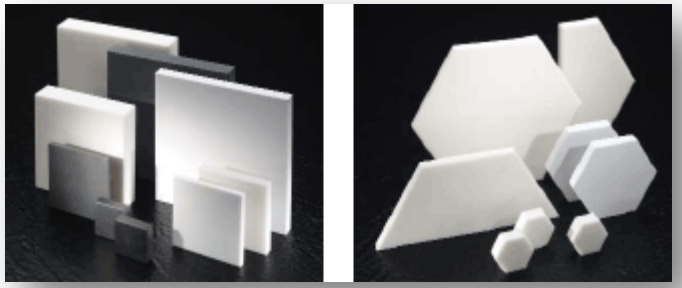
Advanced Armor Materials

- Magnesium
  - Armor Plate, Magnesium Alloy, AZ31B, Applique (MIL-DTL-32333)

- **Ceramics**:
  - Alumina
  - Silicon Carbide
  - Boron Carbide
  - Tungsten Carbide

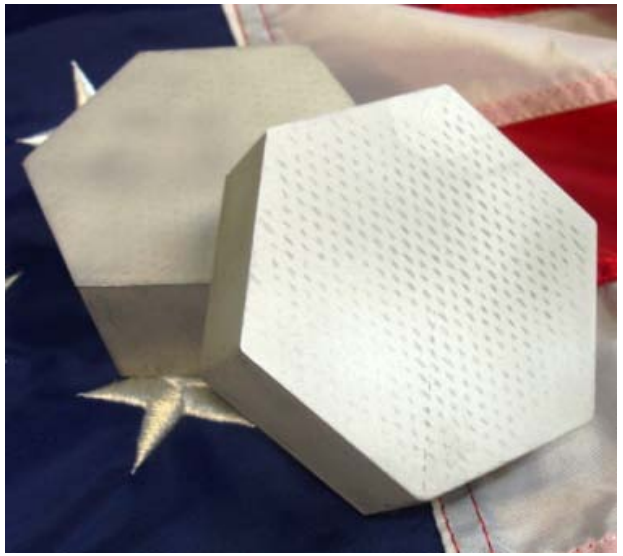
- **Transparent Ceramics**
  - Spinel
  - Sapphire

- Transparent Polymers
  - Poly(methyl methacrylate) (PMMA)
    - Ex. Plexiglass
  - Polycarbonate
    - Ex. Lexan



Armor Material Research

- Lightweight and High Ballistic Performance
  - Armors using multiple materials
    - Metal laminate
    - Metal combined with ceramic
    - Glass combined with plastic
  - Composite Armor
    - Metal encapsulated ceramic
    - Metal matrix composite
    - Composite laminates
  - 3D woven fiber
- Material Characterization for M&S Support
  - High strain rate testing
    - Hopkinson bar tensile test
    - Hopkinson bar compression test
  - Notional Armor Design Evaluation



Importance of Basic & Applied Research

Basic Research

Brittle Materials:
- Material properties
- Processing/synthesis
- Ceramic optimization
- Failure mechanisms
- Failure morphology
- Dynamic behavior modeling
- Laboratory characterization techniques
- Determination of properties relevant to ballistic impact

Mechanics of Composites
- Finite element codes
- Strength of materials
- Analysis of thick composites
- Micro scale model

Penetration Mechanics:
- Constitutive material models
- Hi-strain rate propagation
- Metallurgy
- Hydrocode development

Applied Research

Armor Mechanics:
- -Defeat Mechanism
- Encapsulation Techniques
- Ceramic Optimization
- Multi-hit
- Structural Response
- Ballistic Shock
- Modeling
- Trends analyses
- Armor optimization
- Initial trades studies/analyses

Structural Design Tech:
- Design trades
- LW structural Response

Adv Development

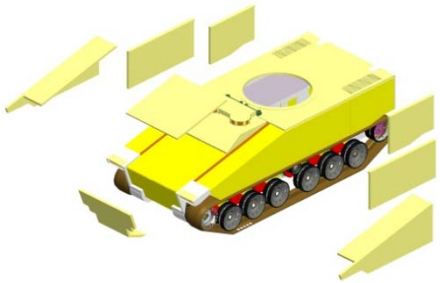
Armor module dev/fab
- Robustness
- Manufacturability
- Attachment design
- Shock transmission
- Affordability
- RAM

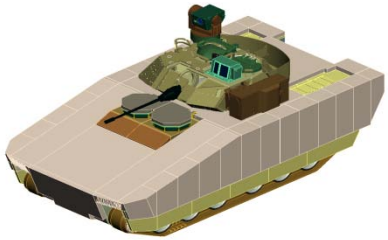
Structure
- Load optimization
- Attachment design
- Shock/vibration
- Damage tolerance
- Affordability
- RAM

Trades analyses
- Performance
- Weight
- Cost

Eng Development

Platform integration, producibility, and performance testing





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INITIATION

*Basic research **critical** to success, and must be a **CONTINUING** activity*

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Ballistic Survivability Modeling

Provides engineering-level & physics-based models to Support technology downselects, design optimization, & evaluation

High-speed analyses of many conditions, threats, & engagement conditions

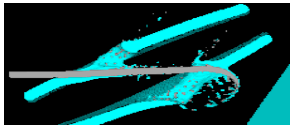
Initial Threat/Target Conditions

Hydrocodes: EPIC, CTH, ALEGRA

physics, penetration models, ...

Component Damage

- *Combined Blast -Fragment*
- *Penetration - Projectiles - Debris - Fragments*
- *Fuel & Ammo Fires*
- *Blast Overpressure*
- *Crew Acceleration*
- *Component Shock*



Engrg Analysis: CPE, ArmorPro

engineering, criticality analysis, ...

Platform Capability

- *Primary Platform Functions (M, F, C)*
- *APS Effectiveness*

Verification & Validation

System Utility

- *Cooperative Survivability*

system evaluation, force-on-force simulations

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Key Ceramic Armor Issues

- ***Material defect detection***
- ***Product assurance of armor package***
  - Experimental techniques to measure
  - Detect damage that matters
- ***Field assessment of armor package integrity***
  - Experimental techniques to measure
  - Detect damage that matters

Armor Standards

- **Army MIL-STD-662F** - V_{50} Ballistic Test for Armor
  - Purpose. The purpose of this standard is to provide general guidelines for procedures, equipment, physical conditions, and terminology for determining the ballistic resistance of metallic, nonmetallic and composite armor against small arms projectiles. The ballistic test procedure described in this standard determines the V50 ballistic limit of armor.
  - Small arms ammunition. All ammunition up to and including 20 millimeters (0.787 inches). A round of ammunition includes a ballistic projectile, propellant charge, charge igniter (primer), and a charge case.
- **NIJ Standard-0101.06** - BALLISTIC RESISTANCE OF BODYARMOR
- **STANAG 2920 Ed2** - STANAG 2920 PPS (EDITION 2) – BALLISTIC TEST METHOD FOR PERSONAL ARMOUR MATERIALS AND COMBAT CLOTHING
- **ATPD 2352** - transparent armor

Armor Areas of Opportunity

- **Reducing Areal Density** (psf)
- **Joining of dissimilar materials**
  - Delamination
  - Galvanic Corrosion
- **Openings**
  - Hatches
  - Doors
  - Windows
- **Interfaces**
  - Panel to panel
  - Panel to structure
- **Attachment to Structures**
  - Removal / Installation
  - Repair Procedures
- **Environmental Concerns**
  - Fire, Smoke and Toxicity
  - Ultra Violet Resistance
  - Oxidation
  - Contamination by Fluids
  - Extreme Temperatures

SUMMARY

- **Significant challenges remain in areas of material development**
- **Need to look at not just basic materials but structural approaches**
- **Modeling and simulation is a critical enabler**

Conclusions / Questions

- Armor has traditionally used common materials, but is always searching for new and better solutions that meet the demands vehicles place on an armor package.

QUESTIONS?